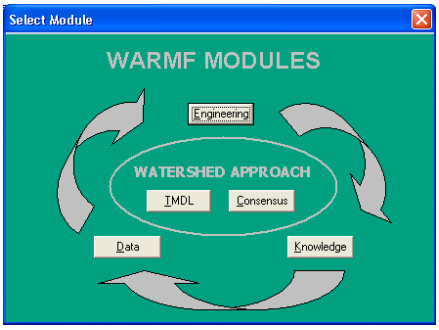
# Watershed Analysis Risk Management Framework (WARMF)

To facilitate TMDL analysis and watershed planning, WARMF was developed as a decision support system. The system provides a road map to calculate TMDLs for most conventional pollutants (coliform, TSS, BOD, nutrients). It also provides a road map to guide stakeholders to reach consensus on an implementation plan. The scientific basis of the model and the consensus process have undergone several peer reviews by independent experts under EPA guidelines. WARMF is now compatible with the data extraction and watershed delineation tools of EPA BASINS. WARMF is organized into five (5) linked modules under one, GIS-based graphical user interface (GUI). It is a very user friendly tool suitable for expert modelers as well as general stakeholders.

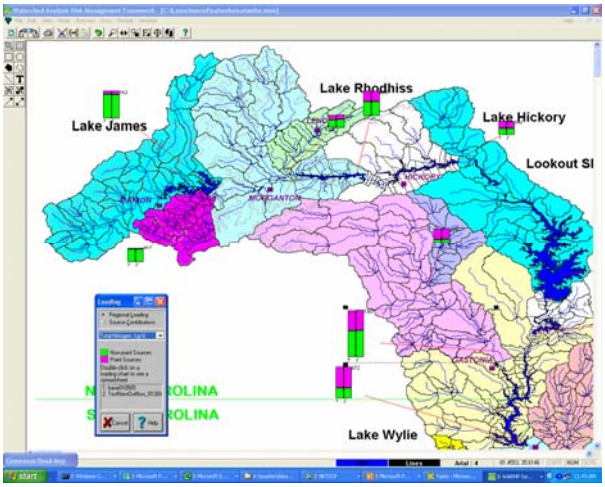



**WARMF Components**

The Engineering Module is a GIS-based watershed model that calculates daily runoff, shallow ground water flow, hydrology and water quality of a river basin. A river basin is divided into a network of land catchments (including canopy and soil layers), stream segments, and lake layers for hydrologic and water quality simulations. Land surface is characterized by land use / land cover and precipitation is deposited on the land catchments to calcuate snow and soil hydrology, and resulting surface runoff and groundwater accretion to river segments. Water is then routed from one river segment to the next, from river segments to reservoirs, and then from a reservoirs to river segments, until watershed terminus is reached. Instead of using export coefficients, a complete mass balance is performed starting with atmospheric deposition and land application as boundary conditions. Pollutants are routed with water in throughfall, infiltration, soil adsorption, exfiltration, and overland flow. The sources of point and nonpoint loads are routed through the system with the mass so the source of nonpoint loading can be tracked back to land use and location. WARMF provides several options for modeling reservoirs using 1D or 2D approaches. The algorithms of WARMF were derived from many well established codes such as ILWAS, SWMM, ANSWERS, WASP.

The Data Module contains meteorology, air quality, point source, reservoir release, and flow diversion data used to drive the model. It also contains observed flow and water quality data used for calibration. The data is accessed through the map-based interface and can be viewed and edited in both graphical and tabular format. The Knowledge Module stores supplimental watershed data, documents, case studies, or reports of past modeling activities for easy access by model users.

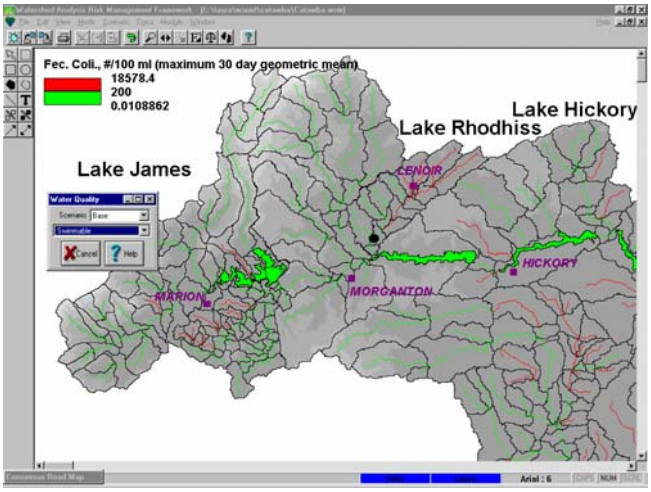
At the center of WARMF are the two watershed approach modules for Consensus building and TMDL calculation. These two modules are roadmaps that provide guidance for stakeholders during the decision making process. The Consensus Module of WARMF provides information in a series of steps for stakeholders to learn about the issues, formulate and evalute alternatives, and negotiate a consensus. Outputs are displayed in colored maps and graphs. A GIS map is used to show the bar charts of pollution loads from various sub regions of the river basin. Another GIS map is used to show the consequence of the pollution loads, in which water bodies suitable for a designated use are shaded green and those not suitable are shaded red. Through the TMDL Module, calculations are made for a series of control points from the upstream to the downstream of a river basin. A road map is provided for the step-by-step procedure. An iterative set of simulations are performed to calcuate various combinations of point and nonpoint loads that the waterbody can accept and meet the water quality criteria of the designated uses. The water quality criteria can be specified for multiple parameters and based on percent compliance.



**WARMF Features**

WARMF can help answer water resource and water quality questions such as:

- What are the cumulative water quality impacts under various watershed management scenarios?
- What are the trade-offs with sewer extension vs. onsite wastewater systems?
- How will regional growth affect water quality?
- How will increased water diversions affect hydrology and water quality?
- Will BMPs such as buffer strips or livestock fencing be effective for nonpoint load reduction?
- What is the TMDL for a 303d listed stream?




The advantages of WARMF include:

- Integrates models, databases, and graphical software into a map-based stand alone tool that does not require ArcView
- Links catchments, river segments, and lakes to form a seamless river basin model which computes soil and surface hydrology, pollutant build up and washoff based on physical principles instead of SCS curve numbers and run off coefficients
- Contains a user friendly GUI and unique decision support tools that allow a variety of stakeholders (including modelers and lay persons) to run the model and to take ownership of their watershed by learning about the science behind their water quality issues
- Calculates TMDLs to meet water quality criteria for beneficial uses
- Uses readily available data from NOAA, EPA, and USGS to predict hydrology and water quality of rivers and lakes
- Models flow, temperature, nutrients, bacteria, dissolved oxygen, sediment transport, periphyton, phytoplankton, and loading from onsite wastewater systems
- Provides several options for modeling reservoirs including 1D, psuedo 2D and CE-QUAL-W2
- Displays sources of point and nonpoint loading using easy-to-understand GIS maps
- Displays water quality status in terms of suitability for fish habitat, swimming, water supply, and other uses with red and green color codes
- Simulates the impact of controls on atmospheric deposition, point source loads, and BMPs for nonpoint source loads such as buffer strips, street sweeping, livestock exclusion, and fertilizer reduction
- Evaluates cost sharing schemes for pollution trading and determines the failure risk of a management plan

WARMF has been applied to over 15 watersheds in the United States and internationally. The studies have addressed the TMDLs of nutrients, sediment, fecal coliform, and the impact of onsite wastewater systems on a watershed scale. The size of river basin applications ranges from the small Mica Creek research watershed in Idaho (10.8 $mi^2$) to the large San Juan Basin of Colorado and New Mexico (16,000 $mi^2$). There is no limit on the size or scale of a potential WARMF application as long as adequate topography data are available.

**References**

Chen, C.W., J. Herr, L. Weintraub, 2004. "Decision Support System for Stakeholder Involvement", Journal of Environmental Engineering, ASCE, Vol 130, No. 6, June 2004, pp.714-721.

Chen, C.W., J. Herr, and L. Weintraub. 2001. "Watershed Analysis Risk Management Framework (WARMF): Update One – A Decision Support System for Watershed Analysis and Total Maximum Daily Load Calculation, Allocation and Implementation" Publication No. 1005181, Electric Power Research Institute, Palo Alto, CA.

Keller, A. 2000. 2000. "Peer Review of the Watershed Analysis Risk Management Framework (WARMF) – An evaluation of WARMF for TMDL applications by independent experts using USEPA guidelines", Technical Report 2000.1000252, Electric Power Research Institute, Palo Alto, CA.